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ABSTRACT

A project designed to convert solid waste to energy is explained in this paper. In April, 1972, an investor-owned utility began to burn municipal solid waste as fuel for the direct production of electric power. This unique venture was a cooperative effort between the City of St. Louis, Missouri, and the Union Electric Company, with financial support from the Environmental Protection Agency. It was and is intended to demonstrate the benefits which could accrue to a metropolitan area by utilizing this technique for solid waste management and the recovery of resources. Conceived under the premises that if residential solid waste were properly prepared, and if it were to replace only a small percentage of the fuel fired to coal-fired boilers, the effects would be little, if any, different than if the fuel were entirely coal. The potential benefits include an environmentally acceptable means of solid waste disposal, conservation of irreplaceable natural resources, more effective control of land use, and economic advantages to both the utility and the public. The scope, processes, and outcomes of the project are all detailed accompanied by diagrams, charts, and statistics. (BL)

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FROM SOLID WASTE TO ENERGY

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FROM SOLID WASTE TO ENERGY

In April, 1972, for the first time in the United States, and perhaps for the first time in the world, an investor-owned utility began to burn municipal solid waste as fuel for the direct production of electric power. This unique venture is a cooperative effort between the City of St Louis, Missouri and the Union Electric Company, with financial support from the Environmental Protection Agency. It is intended to demonstrate the benefits which could accrue to a metropolitan area by utilizing this technique for solid waste management and the recovery of resources. The potential benefits include an environmentally acceptable means of solid waste disposal, conservation of irreplaceable natural resources, more effective control of land use, and economic advantages to both the utility and the public.

Until recently, efforts to recover energy from solid wastes have been somewhat of a rarity in the United States. When such efforts have been made, they have generally been confined to the generation of steam, for either in-plant use or for sale. Unfortunately, such steam generators must be quite sophisticated and are correspondingly costly, and in order to be effective in resource recovery, must have markets for the steam they are designed to produce. Satisfactory markets for steam are not always readily available.

Consider, however, large, efficient, existing utility power plants, already integral with systems for producing, distributing and marketing electricity. It follows that if a means were devised to burn refuse as fuel in existing power plant boilers, without creating significant adverse effects, the matter of finding a market for the energy available from refuse automatically would be resolved, since utilities can market essentially all of the power they have the capability of producing.

The St. Louis project was conceived under the premises that if residential solid waste were properly prepared, and if it were to replace only a small percentage of the fuel fired to coal-fired boilers, the effects would be little, if any, different than if the fuel were entirely coal. Although coal-fired boilers are not without operating problems of their own, a comprehensive study concluded that such problems would not be significantly increased, if increased at all, by burning prepared refuse as supplementary fuel. This concept was found attractive enough for the Union Electric Company to offer the use of two of its major power-producing boiler units for full-scale tests, and to contribute a substantial sum toward the installation of facilities to implement these tests.

At the present time, the solid wastes being processed for use as fuel consist of mixed municipal refuse generated in residential areas. No bulky materials, such as appliances, furniture or significant quantities of automobile tires, or industrial and commercial wastes, presently are being processed. However, certain selected industrial and commercial wastes may be processed later.

As shown in Figure No. 1, the initial preparation process purposely was kept as simple as possible, consisting merely of the equipment required for milling the raw refuse to particle sizes of 1-1/2 inches and less and for removing the magnetic metal. Although consideration was given in the original design to the use of air-gravity separation for the purpose of removing at least part of the non-burnables, this processing step was not incorporated at that time.

Initial operations demonstrated that when unclassified solid waste was burned in suspension, with only magnetic metal removed prior to firing, several undesirable effects resulted. These effects included severe pipe line abrasion, stoppage of pneumatic feeders due to particles of non-ferrous metal becoming lodged between the rotors and housings, and the bottom ash containing not only inert materials such as glass, non-ferrous metals and ceramics, but also particles of wood, dense plastics, rubber and leather which had sufficient mass to prevent their being burned in suspension. The significance of these effects was great enough to result in the decision to install an air-density separator, and the installation of this device is now being completed. Figure No. 2 shows schematically the processing facilities with the air-density separator.

The air-density separator as shown on Figure 3, also is a very simple device, consisting of a chamber into which the milled solid waste is introduced, with an upward current of air of sufficient velocity to separate the light, fluffy, readily combustible fraction of the waste from the heavy particles. It is anticipated that the operational difficulties experienced with unclassified waste will be minimized when the air-density separator is in operations. Some pipe line abrasion is still expected, however, and special care must be taken in the design of pneumatic piping, particularly at elbows and other points of potential wear.

The storage and handling of milled solid waste also requires special consideration. This material has the tendency to compact under its own weight into a laminar, springy mass. The power requirements for equipment to handle large volumes of milled waste are very easily underestimated.

The processed material, in the St Louis prototype project, is hauled by means of self-unloading transport trailers from the processing plant to the power plant, a distance of about 18 miles. If it were feasible to locate the processing facilities near the power plant, it would be possible to eliminate truck transport by pneumatically conveying the supplementary fuel directly to the boilers from the storage bin.

Figure No. 4 shows diagramatically the receiving and firing facilities at the power plant. Again, these facilities could be simplified even more if the processing plant were near the boilers in which the material is burned. The supplementary fuel is fired pneumatically and independently of the normal fuel. The boilers are about 700 feet from the pneumatic firing systems.

A cross-section of the boilers used in the St. Louis prototype installations is shown on Figure No. 5. Built by Combustion Engineering, Inc., the two boilers are tangentially-fired, each with a nominal capacity of 125 megawatts. They are fitted to burn either pulverized coal or gas. The furnaces are rectangular, with four pulverized coal burning ports in each of the four corners. The refuse burning nozzles were installed between the two middle coal-burning ports in each corner. No other modifications to the boilers were necessary.

At full load, the quantity of refuse for each boiler equivalent in heating value to 10 per cent of the coal is about 12.5 tons per hour, or 300 tons per 24-hour day. The facilities were designed to permit firing of refuse at an approximate fuel replacement rate of up to 20 per cent, 24 hours per day, but only 5 days per week, since City residential solid waste collections are scheduled on a 5-day-per-week basis. No difficulty in boiler operation accruing from an interrupted refuse firing schedule has so far occurred.

The prepared refuse is fired at a constant rate, thereby furthering the concept of simplicity. The existing boiler combustion controls automatically vary the rate of firing of the pulverized coal or gas to accommodate variations in the heat requirements of the boilers. Should the boiler go out of service suddenly, for any reason, an electrical interlock will immediately stop the feeding of refuse, although the pneumatic blowers will continue to function in order to clear the pipe lines of any refuse remaining in them.

An appraisal of operating results up to this time must be considered to be of a preliminary nature, since the testing program is not complete. The original evaluations of the process were based upon the refuse firing rate being equivalent to 10 per cent of the heat requirement of the boiler. In actual practice, a 15 per cent firing rate has been consistently achieved and a 20 per cent firing rate, or even greater, appears to be reasonable. There has been no evidence of carry-over of unburned particles into the back passes of the boiler, nor any evidence of slagging resulting from the firing of refuse.

The testing program provides for the investigation of what, if any, effects upon corrosion potential accrue from the combination firing of coal and refuse. The program also provides for investigations of the air pollution effects of the process. Since these investigations cover a relatively long period, no data are yet available on their results.

As background for further discussion, it is appropriate to review briefly a comparison of some of the more important characteristics of coal and refuse. Figure No. 6 compares ranges of proximate and ultimate analyses for the two fuels, based upon limited investigations made during the preliminary studies. The indicated major differences are in moisture and carbon content. The heating value for refuse, assumed in this case to be an average of 5,000 Btu per pound, is somewhat less than half the Btu value for Illinois bituminous

coal. Sulfur in the refuse was found to be low, as was expected. Chlorine was found to be considerably higher in refuse than in washed coals, which are represented by the analyses shown, but of the same order of magnitude as that in run-of-mine coals.

A comparison of ash analyses for refuse and coal is shown in Figure No. 7. In each case the ash was found to be high in silica. Significant differences are indicated in ferric oxide, alumina, lime and sodium oxide.

Figure No. 8 compares the ash fusion temperatures of refuse and coal. The remarkable similarity of ash fusion temperatures for the two fuels is of particular interest.

The St. Louis prototype installation has included a comprehensive analytical program. Through February, 1973, 210 samples of the fuel delivered to the power plant were analyzed. The average values derived from these analyses are as follows:

Moisture	29.5 per cent
Sulfur	0.11 per cent
Chlorine	0.29 per cent
Ash	20.3 per cent
Btu/lb.	4672

All of these values are in the same range as those determined during the preliminary investigations.

It should be borne in mind that all of the analyses discussed in the preceding are from samples of unclassified solid waste. It is anticipated that certain differences in the analyses will result from sampling only the light, fluffy fractions. For example, it is reasonable to assume that the heating value will increase, that the ash content will decrease and that the chlorine content also will decrease.

The relative economics of utilizing refuse as supplementary fuel show promise of being attractive. The basic economic elements consist of: (1) the total unit cost of processing, transporting and firing the refuse, including those costs accruing to the utility; (2) the costs of alternate means of residential solid waste disposal; (3) the value of the magnetic metals and other materials which potentially can be recovered from the non-burnable fraction; and (4) the value of the milled refuse as a replacement for the normal fossil fuel. Under almost any situation, the capital cost of the facilities required for application of the process would be substantially less than that of conventional incineration facilities. Total unit costs per

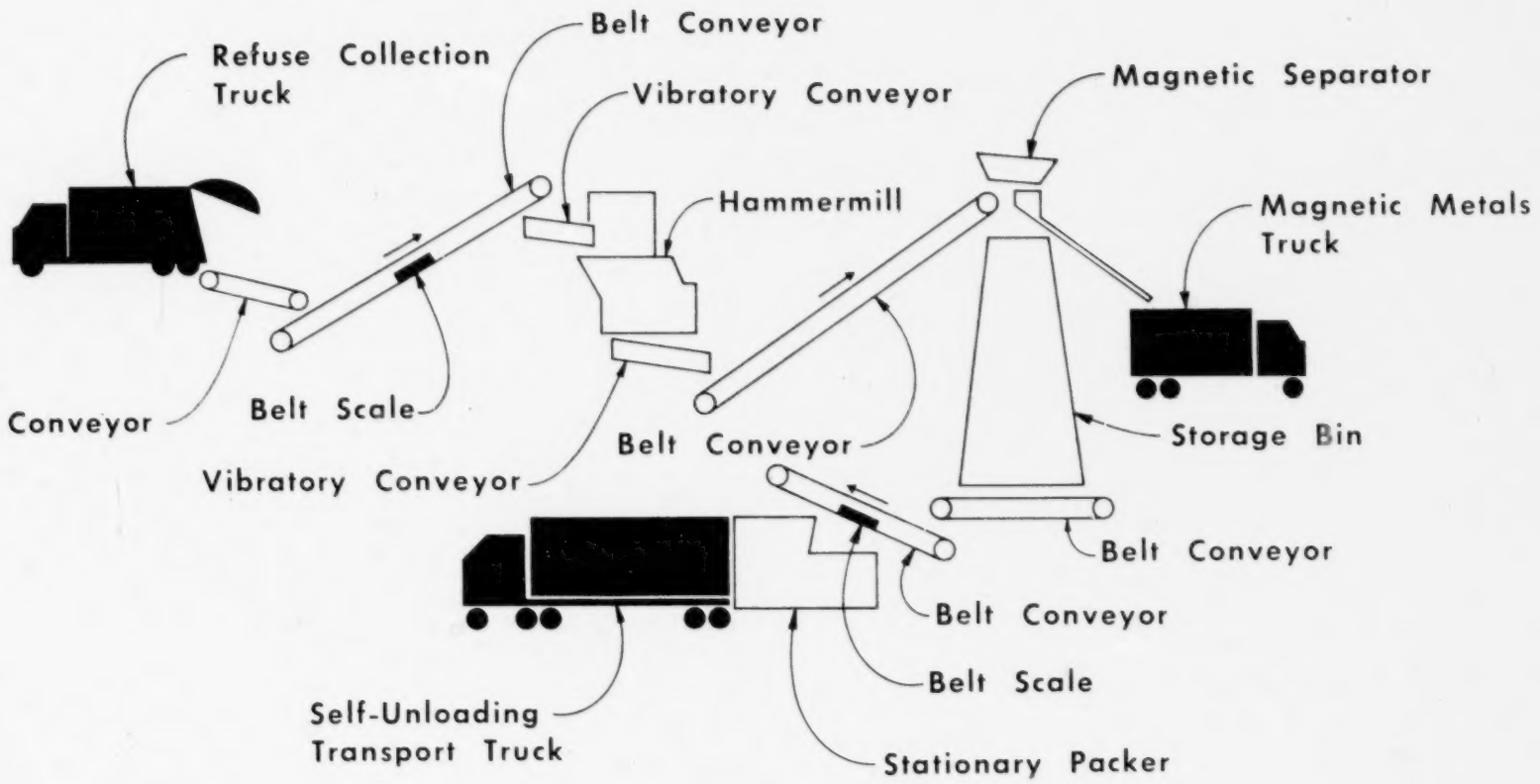
ton, including operation, maintenance and amortization, could be comparable to those of sanitary landfill when the landfill is in a location remote from the point of refuse generation.

Utility fuel costs are rising rapidly, but even under present conditions the value of refuse as fuel could be significant. When all of the economic elements are considered, the cost of residential solid waste disposal by this means could be highly attractive in many of the metropolitan areas of the United States.

Present indications are that almost all fossil fuel-fired boilers, providing they have ash handling capability, could be adapted for burning refuse. Some, of course, could be more easily adapted than others. There also appears to be no reasons why the combination burning of refuse with gas or oil, as well as with coal, would not be practical.

The capability of existing suspension-fired boilers to consume municipal solid waste is great enough to permit the process to serve as a principal means of refuse disposal for many metropolitan areas, even when the supplementary fuel is fired as only 10 per cent of the total fuel requirements. A 600 megawatt unit, for example, could at full load consume on the order of 1,400 tons of prepared solid waste per day at the 10 per cent fuel replacement.

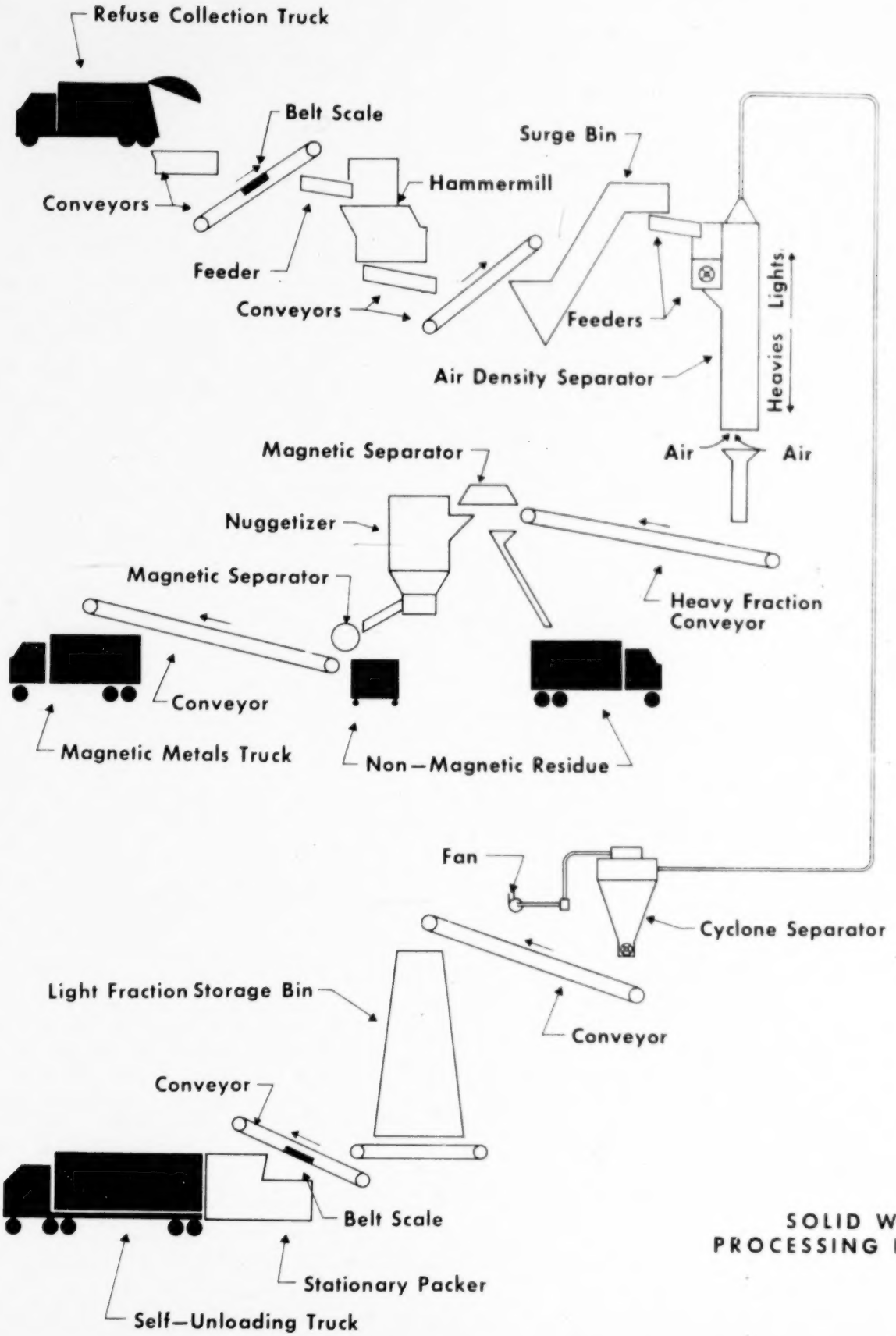
The process shows promise of having fairly extensive application once a satisfactory cooperative arrangement can be worked out between the utility and the solid waste supplier. It could provide an economical means of disposing of large quantities of solid wastes in an environmentally acceptable manner, effect recycling by the direct recovery of electrical energy, conserve irreplaceable natural resources, and to some degree, assist in the control of air pollution. Indications are that these benefits could be achieved by merely achieving cooperation between municipalities and utilities, by using commercially available equipment, and by applying already tried and proven technology.



REFUSE PROCESSING FACILITIES

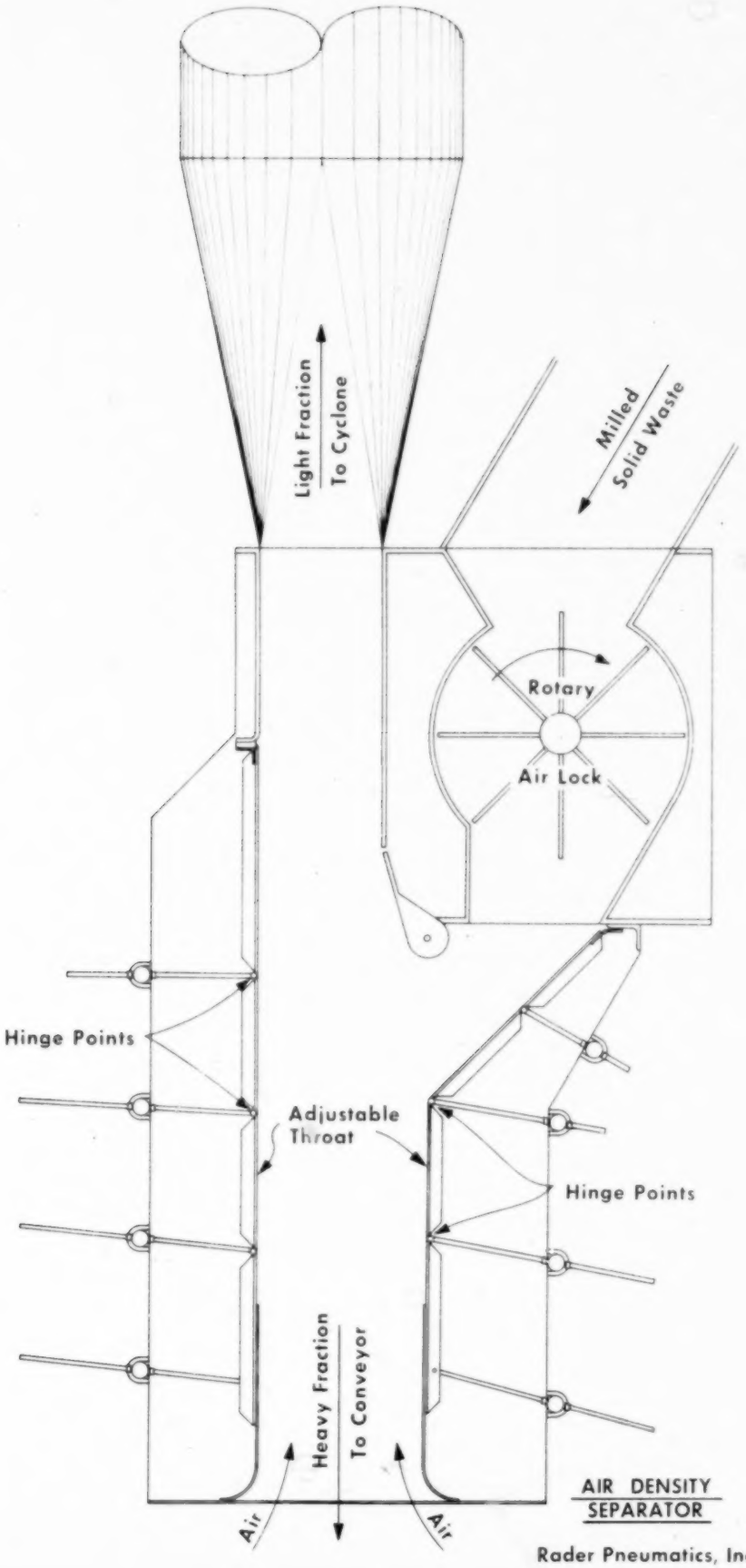
WITHOUT AIR-DENSITY SEPARATOR

Figure 1



SOLID WASTE PROCESSING FACILITIES

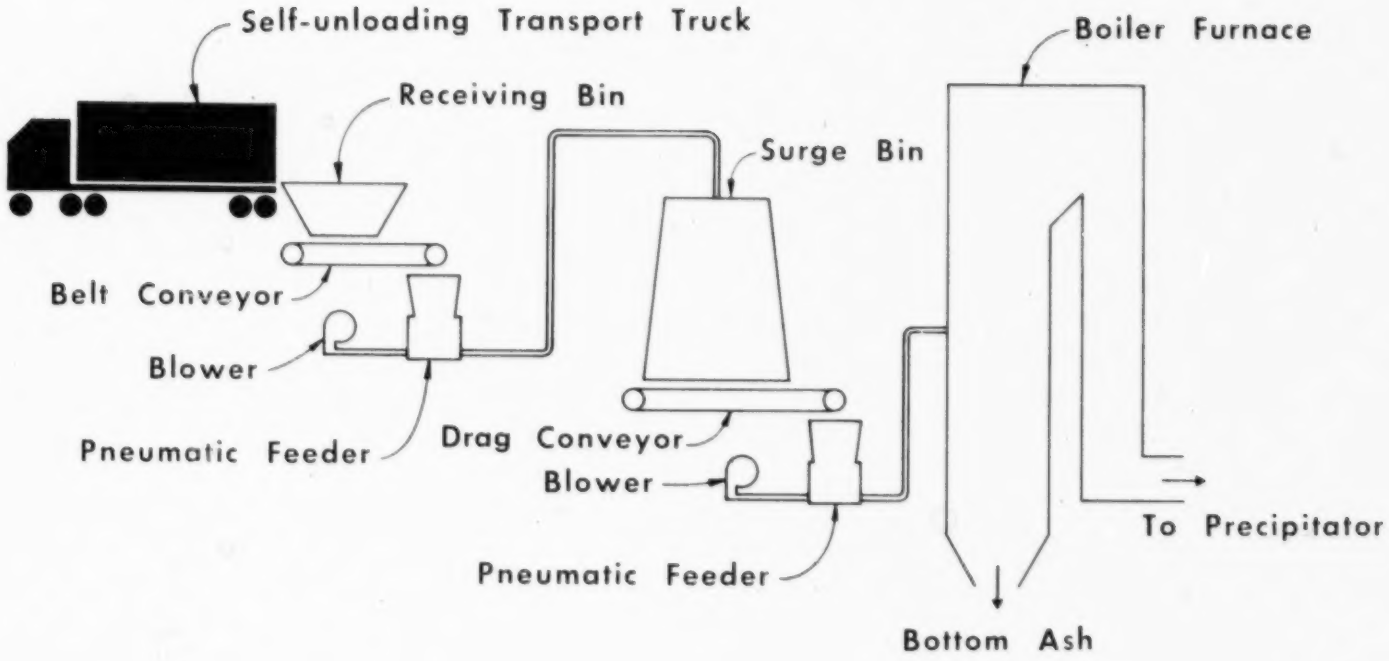
Figure 2



AIR DENSITY
SEPARATOR

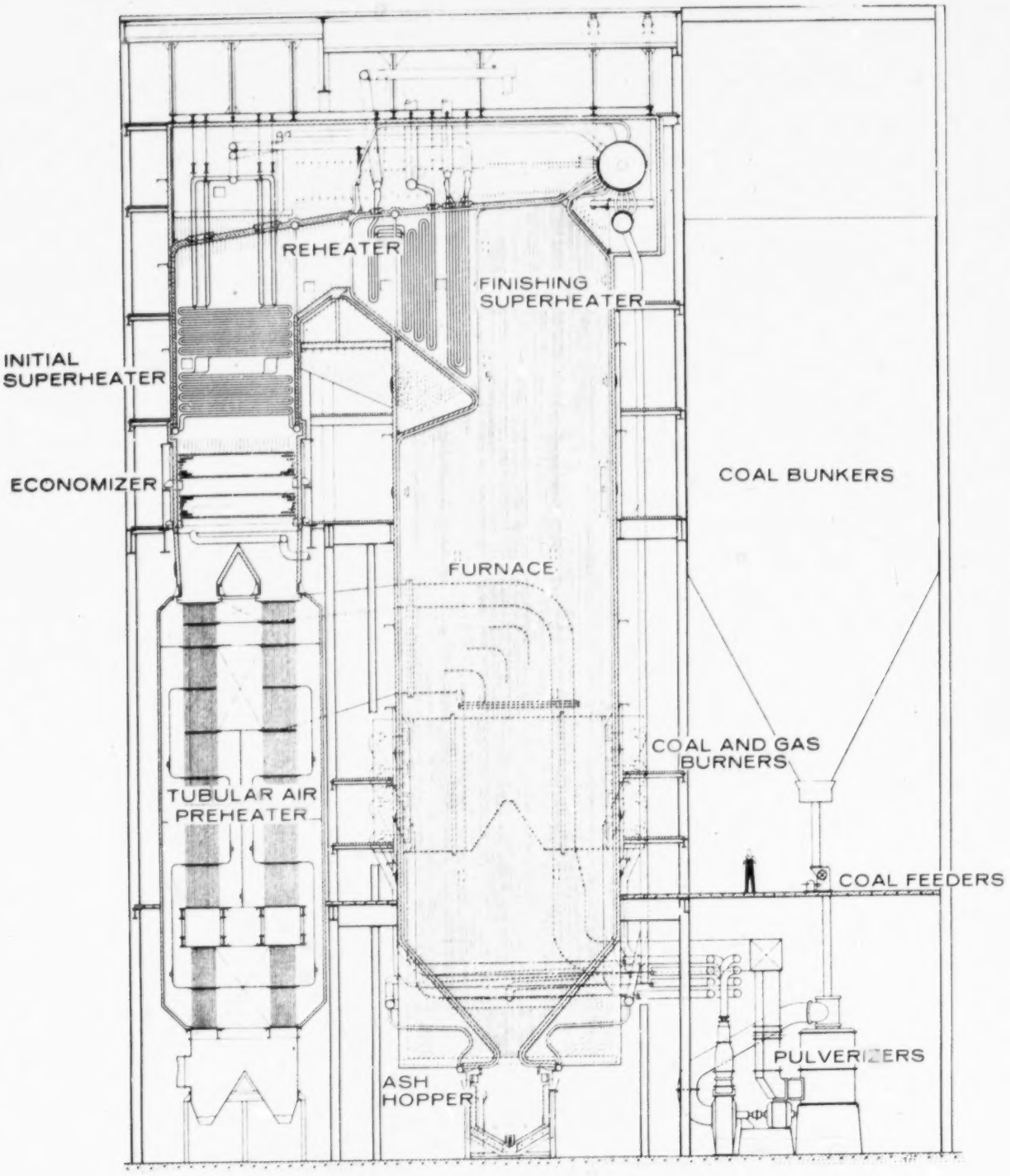
Rader Pneumatics, Inc.

Figure 3



SUPPLEMENTARY FUEL RECEIVING AND FIRING FACILITIES

Figure 4



MERAMEC UNIT NO. 1
UNION ELECTRIC COMPANY
COMBUSTION ENGINEERING, INC.

Figure 5

REFUSE AND COAL ANALYSES
RANGES OF COMPOSITION
(As Received)

	Refuse[a] %	Coal[b] %
Proximate Analyses		
Moisture	19.69 – 31.33	6.20 – 10.23
Ash	9.43 – 26.83	9.73 – 10.83
Volatile	36.76 – 56.24	34.03 – 40.03
Fixed Carbon	0.61 – 14.64	42.03 – 45.14
Btu per Pound	4,171 – 5,501	11,258 – 11,931
Ultimate Analyses		
Moisture	19.69 – 31.33	6.20 – 10.23
Carbon	23.45 – 33.47	61.29 – 66.18
Hydrogen	3.38 – 4.72	4.49 – 5.58
Nitrogen	0.19 0.37	0.83 – 1.31
Chlorine	0.13 – 0.32	0.03 – 0.05
Sulfur	0.19 – 0.33	3.06 – 3.93
Ash	9.43 – 26.83	9.73 – 10.83
Oxygen	15.37 – 31.90	9.28 – 16.10

(a) From three samples of St. Louis refuse, with magnetic metals removed.

(b) From three samples of Union Electric Company coals.

Figure 6

REFUSE AND COAL ASH ANALYSES
RANGES OF COMPOSITION
(As Received)

	Refuse [a] %	Coal [b] %
MINERAL ANALYSES (Ignition Basis)		
Phosphorus Pentoxide	1.02 – 4.69	0.08 – 0.20
Silica	48.93 – 60.07	45.52 – 46.93
Ferric Oxide	3.50 – 5.92	15.51 – 25.29
Alumina	5.02 – 13.72	16.54 – 18.53
Titania	0.74 – 1.60	0.81 – 1.01
Lime	7.54 – 18.19	2.13 – 6.31
Magnesia	1.14 – 1.91	0.80 – 0.92
Sulfur Trioxide	1.84 – 12.54	1.41 – 6.28
Potassium Oxide	1.57 – 2.70	1.70 – 1.78
Sodium Oxide	3.62 – 5.95	0.30 – 0.62
Undetermined	0.08 – 0.69	0.39 – 5.25

(a) From three samples of St. Louis refuse, with magnetic metals removed.

(b) From three samples of Union Electric Company coals.

Figure 7

ASH FUSION TEMPERATURE RANGES
REFUSE AND COAL

	Reducing °F	Oxidizing °F
Refuse [a]		
Initial Deformation	1890 – 2070	2030 – 2100
Softening (H=W)	2190 – 2360	2260 – 2420
Softening (H=½W)	2210 – 2390	2290 – 2450
Fluid	2400 – 2560	2480 – 2700
COAL [b]		
Initial Deformation	1940 – 2010	2020 – 2275
Softening (H=W)	1980 – 2200	2120 – 2455
Softening (H=½W)	2180 – 2220	2260 – 2470
Fluid	2250 – 2600	2390 – 2610

(a) From three samples of St. Louis refuse, with magnetic metals removed.

(b) From three samples of Union Electric Company coals.

Figure 8